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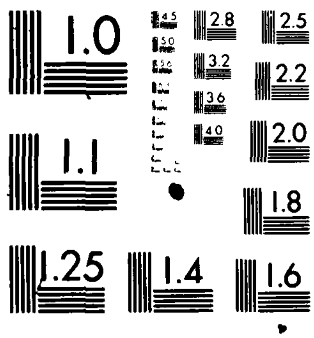

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ENGINEERING DEVELOPMENT ESTABLISHMENT

INVESTIGATION OF THE PERFORMANCE OF A FORD 4.1 L 6 CYLINDER SI ENGINE OPERATING ON METHANOL ISO-BUTANOL GASOLINE FUEL BLENDS (U)

BY

D.J. AYERS

PUBLICATION EDE 10/82

Prepared and issued under my direction.

Evans

(P.J.A.Evans)
Brigadier
Head of Establishment

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4.1 L 6 CYLINDER SI-ENGINE

OPERATING ON METHANOL ISO-BUTANOL GASOLINE

FUEL BLENDS (U)

BY

D.J. AYERS

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SUMMARY

A laboratory investigation into the relative performance of a Ford Falcon 4.1 L 6 cylinder in line engine when operated on both super grade gasoline and blends of non-leaded gasoline, methanol and iso-butanol showed that the engine operated satisfactorily on fuel blends containing up to 30% total alcohol. For the blends thermal efficiency of the engine for most conditions was improved but some torque loss was experienced under full throttle conditions especially at lower engine speeds. This loss increased with increasing proportion of alcohols in the fuel.

Maribyrnong
July 1982

ENGINEERING DEVELOPMENT ESTABLISHMENT

INVESTIGATION OF THE PERFORMANCE OF A FORD 4.1 L 6 CYLINDER SI-ENGINE OPERATING ON METHANOL ISO-BUTANOL GASOLINE FUEL BLENDS (U)

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INTRODUCTION

1. As part of Project DST 76/049 (Methanol as a Fuel for Defence Purposes) a standard Ford Falcon 4.1 L, 6 cylinder engine was subjected to a laboratory investigation to determine the effects on engine performance when operating on fuel blends of gasoline, iso-butanol and methanol.

AIM

2. To determine the performance characteristics of the engine when operating on various fuel blends and to compare these results with those obtained when operating on commercial premium grade gasoline.

EQUIPMENT FOR TEST

Engine

3. A Ford I6. 4.1 L, 6 cylinder in line engine fitted with an aluminium alloy cylinder head, a Stromberg BX carburettor fitted with a 360 main jet and Motorcraft AGR 42 spark plugs (as recommended by the manufacturer) was used for the investigation.

4. All standard exhaust emission controls were retained and were operating normally except that the valve controlling hot air from the exhaust manifold shroud to the air intake (designed to reduce warm-up time and thus emission levels) was closed. Except for ignition timing and fuel mixture strength adjustments during the investigation, the engine complied with manufacturer's specifications. The alternator was retained although it was not connected to the charging circuit.

FUELS

5. The fuels examined during the tests consisted of blends of methanol, iso-butanol and gasoline. Methanol can be used in a number of ways to augument transport fuels. For these tests, its use as a gasoline extender was examined.

6. Throughout the report the fuels and blends used are identified as:

a. Super. Premium Grade Gasoline.

b. Methanol Fuel (MF). This blend, referred to as methyl fuel, is a mixture by volume of 75% methanol to 25% iso-butanol.

c. Reformate (R). Unleaded gasoline.

d. 20 MFR, 30 MFR, 40 MFR. Blends respectfully of 20, 30 and 40% methyl fuel with 80, 70 and 60% reformate by volume.

7. Methanol and gasoline although usually miscible in all proportions may experience phase separation in the presence of about 0.3% of water at temperatures as high as 15°C. Water tolerance increases with increasing temperatures. Higher alcohols act as emulsifiers and stabilize mixtures of gasoline and methanol, increasing its tolerance to included water and low temperatures without separation. Moreover some methanol production processes yield significant proportions of higher alcohols such as iso-butanol with a saving in production costs over pure methanol production.

8. Two types of gasoline were used, commercial premium grade gasoline and an unleaded gasoline produced from low octane naptha feedstock. This gasoline is known as Reformate (R) and is one of the principal ingredients of pool gasoline from which motor gasoline is produced.

9. Fuel blends were made up at the beginning of each week and any fuel remaining at the end of the week was discarded.

10. The properties of the fuels used for the tests are contained in Annex B.

PROCEDURE

11. Torque, efficiency and fuel consumption were measured for the various full and part throttle torque conditions shown in Table 1. In addition, testing was carried out to determine the minimum spark advance timings for best torque (MBT) conditions. The standard main jet was fitted and the ignition timing was standard.

TABLE 1 - TEST SCHEDULE

Speed (r/min) (a)		Torque (Nm) (Nominal % of Full Throttle Torque for Super) 30 (b)	50 (c)	75 (d)	85 (e)	Full Throttle for each blend (f)
1	1500	92	154	214	261	-
2	2000	92	154	216	262	-
3	2500	92	152	214	258	-
4	3000	88	147	205	250	-
5	3500	80	134	188	228	-
6	4000	72	120	165	200	-

A limited amount of testing was also carried out using a variable carburettor main jet to determine the effect on performance and efficiency caused by changing the fuel equivalence ratio (ER). By definition ER is the ratio of stoichiometric massair/fuel ratio to the actual mass air/fuel ratio and is consequently less than unity for lean mixtures and greater than unity for rich mixtures.

12. The engine was mounted on a laboratory bed plate and was run-in using a "37 Hour Break In Schedule for Dynamometer Engine Development" supplied by Ford Motor Company Australia. Power was absorbed by a water brake dynamometer. Parameters measured and instrumentation used are detailed in Annex A.

RESULTS AND DISCUSSION

13. Torque measurements for full throttle runs have been corrected to standard atmospheric conditions of 98.2 kPa dry barometric pressure at 29.5°C. Test cell ventilation was controlled in order to maintain intake air temperature close to standard.

14. Initial results showed that 40 MFR would not operate satisfactorily in the standard engine especially at low speeds where the torque drop off was such that instability occurred especially under part throttle conditions. For this reason only limited running was carried out using this blend and except for some variable jet running results, these have not been included.

15. Full throttle torque (FT) for both 20 and 30 MFR, shown in Fig 1 was below that of super, however 20 MFR produced essentially the same torque as super above 3000 r/min. Maximum difference in torque occurred at 1500 r/min with 30 MFR being some 7.0% below super and 20 MFR 4.5% below. The blends have a decreased calorific value compared with gasoline (10% and 14.5% respectively) although this is partially offset by a small (2-3%) increase in volumetric efficiency due to the charge cooling effect of the blend fuels higher latent heat of vaporisation. (Ref Fig 10).

16. The effect of the blends on engine thermal efficiency is shown in Figs 2-6. At full throttle the maximum value for all blends occurs at 2000 r/min with the curves being similar in shape. Efficiency increases with percentage of methyl fuel and rises from a best for super of 30% to 32.5% and 33.5% respectively for 20 and

30 MFR. The improvement in efficiency is due partly to the small increase in volumetric efficiency but mainly to the leaner operating mixtures of the blends. Over the speed range 30 MFR air/fuel mixtures were 10-12% leaner and 30 MFR approximately 15% leaner than for super.

17. Engine fuel consumption throughout the tests was measured on a mass basis. At FT, Brake Specific Fuel Consumption (BSFC) based on mass, showed super and 20 MFR to be similar above 2500 r/min with super better below, and 30 MFR some 4% worse than either. As fuel is generally stored, sold and used on a volumetric basis Fig 7 shows FT BSFC curves based on this. They show 20 MFR to be the best throughout the range with super and 30 MFR some 2-5% and 3% respectively poorer.

18. Torque vs ignition timing for super is shown in Fig 8. This and similar graphs for the blends were used to determine full throttle MBT ignition settings. Interpolation from the various graphs showed no significant difference in MBT timing between super and the blends. For speeds 3000-4000 r/min inclusive the standard ignition timing is close to that required for MBT. Below this the manufacturers have retarded the ignition timing from MBT to prevent detonation occurring when operating under high torque low speed conditions. As the blended fuels have a higher octane rating than super it is possible to advance the ignition timing slightly at the lower speeds with a consequent improvement in torque characteristics without detriment to the engine.

19. The effect of change in ER on engine torque is shown in Fig 9. 40 MFR was chosen for the variable jet running, as it was expected the greatest variation would occur with this blend. The ER value for the standard main jet is indicated. As expected the engine operating with the standard main jet is operating too lean and a charge in jet size to increase the operating ER by 0.1 would improve the torque.

CONCLUSIONS

20. The engine as supplied by the manufacturers will operate satisfactorily on fuel blends containing up to 30% MF. Higher proportions of MF cause torque drop off increase until with 40% MF instability occurs especially under conditions of high load low speed and under part throttle conditions.

21. Thermal efficiency of the engine improves with increasing proportion of MF in the blend due principally to leaner mixtures, and also, to a small extent, to higher compression pressures resulting from increased volumetric efficiency due to charge cooling effects.

22. No significant difference in MBT ignition timing was found between super and the blend fuels, although, under low speed high load conditions the blend fuels could be expected to tolerate a greater advance in ignition timing than super. Road testing would be required to confirm this.

23. The torque decrease experienced with blend fuels could be reduced by an increase in main jet size.

24. Vehicle operating range would be similar with super and 30 MFR and slightly greater (approximately 3%) with 20 MFR.

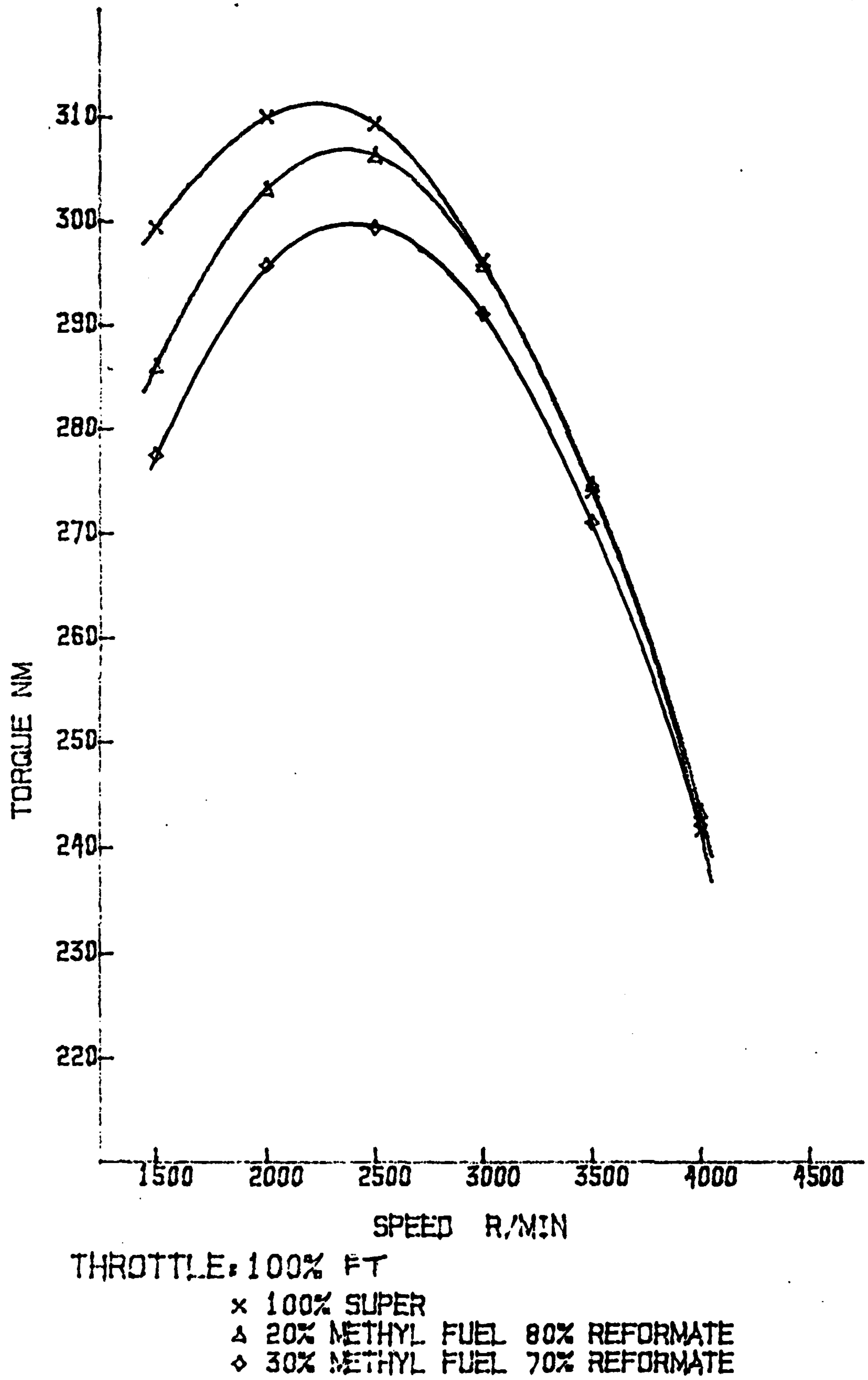

FIG 1 - TORQUE vs ENGINE SPEED (100% FT)

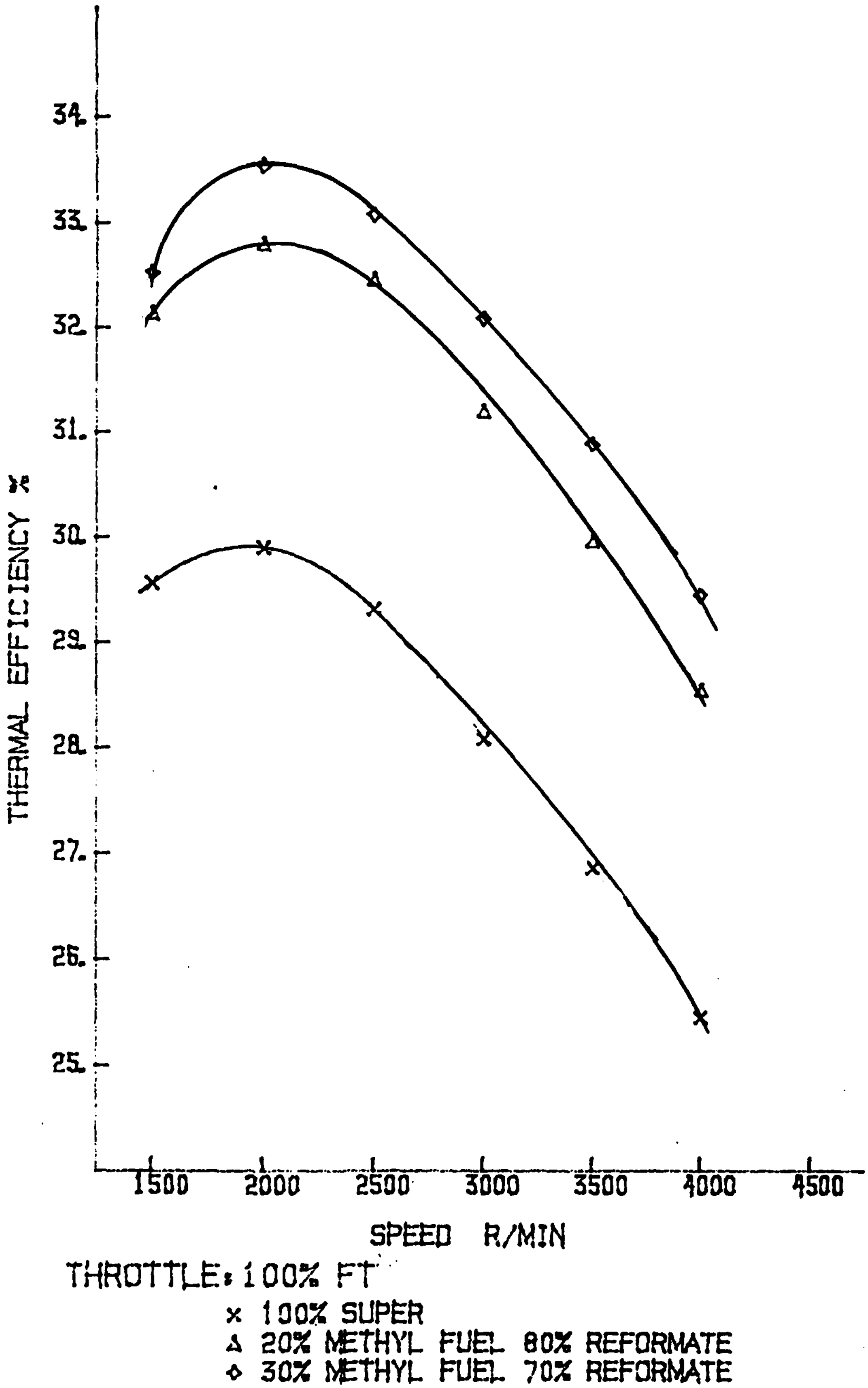

FIG 2 - THERMAL EFFICIENCY vs ENGINE SPEED (100% FT)

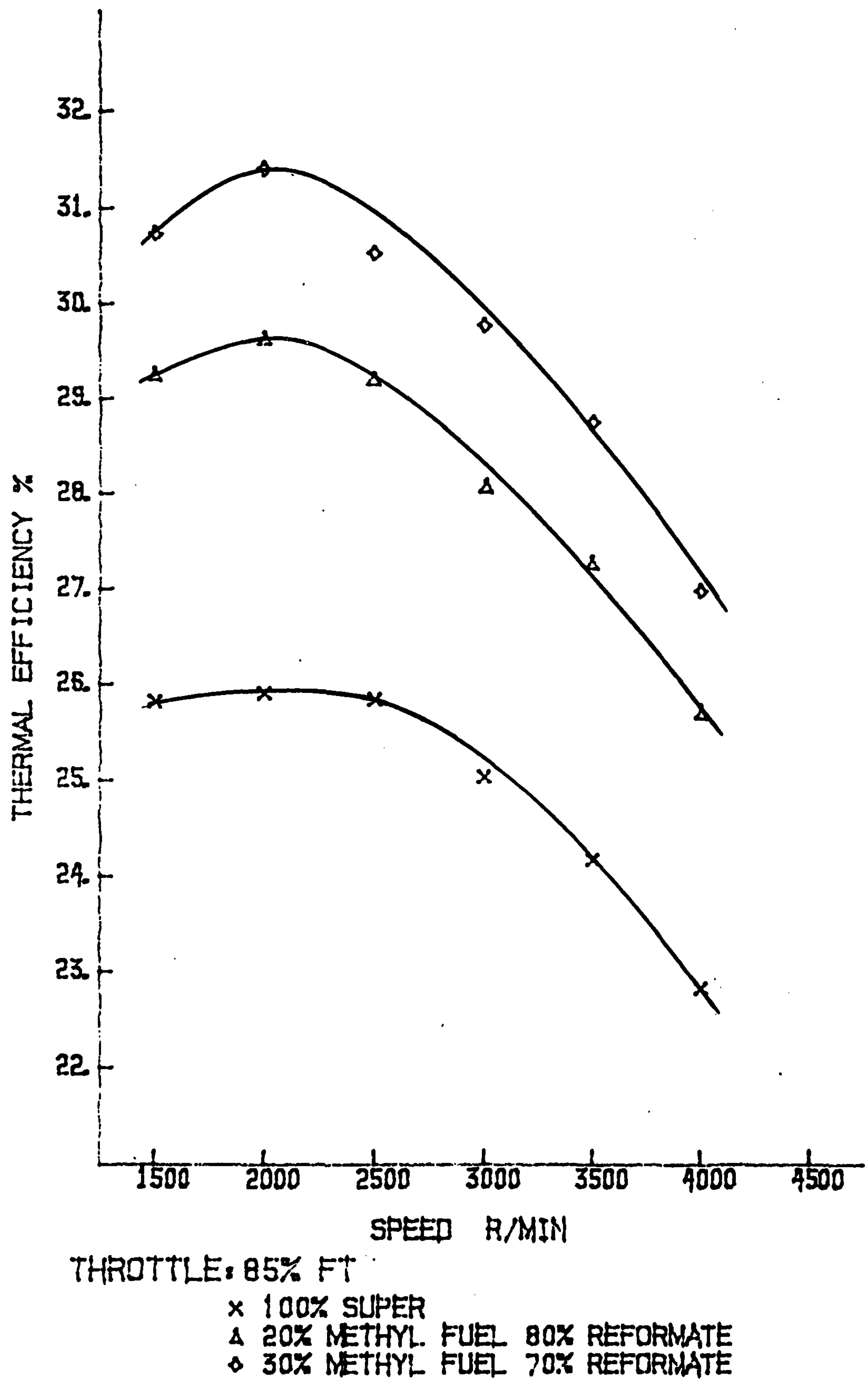

FIG 3 - THERMAL EFFICIENCY vs ENGINE SPEED (85%)

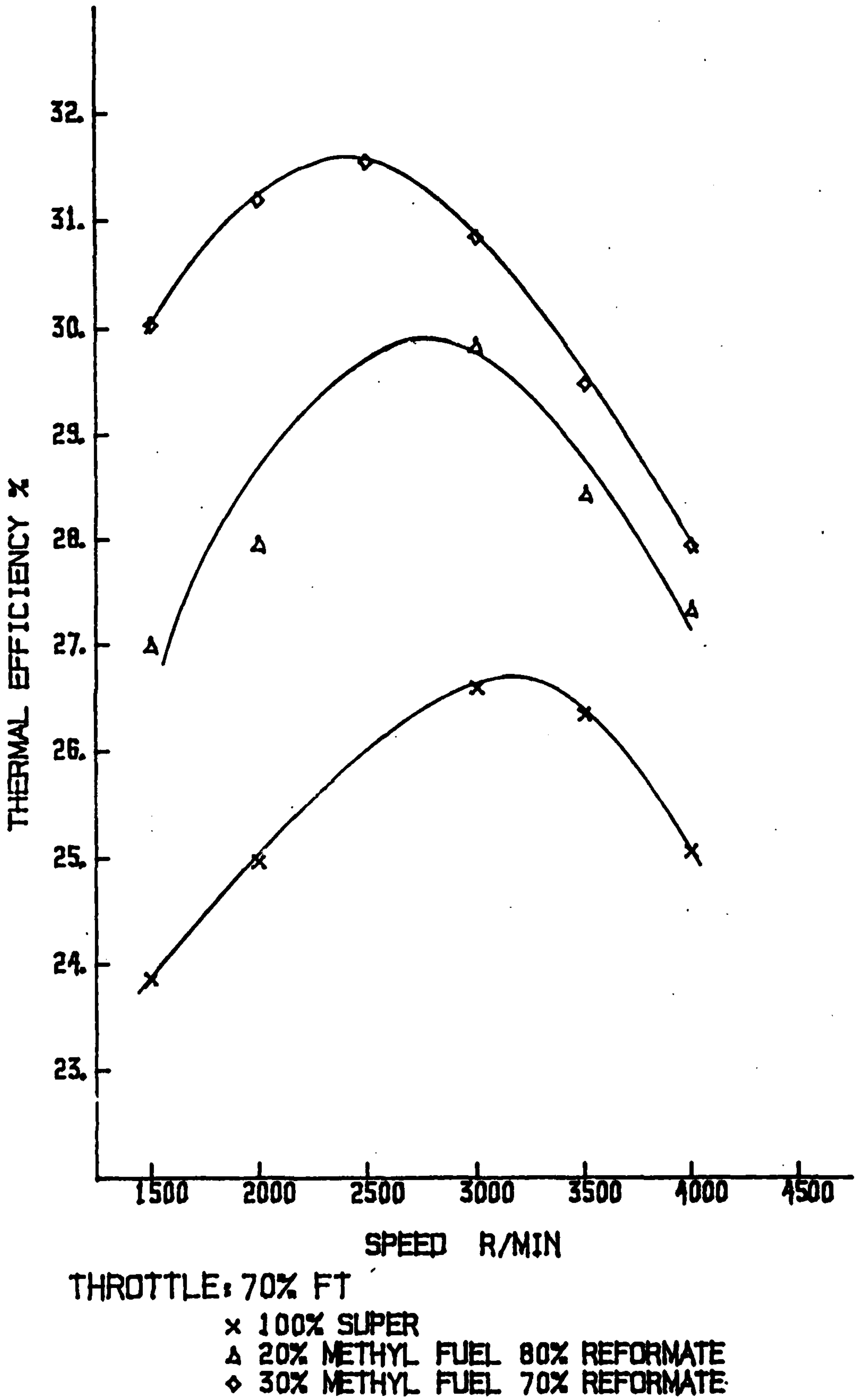

FIG 4 - THERMAL EFFICIENCY vs ENGINE SPEED (70% FT)

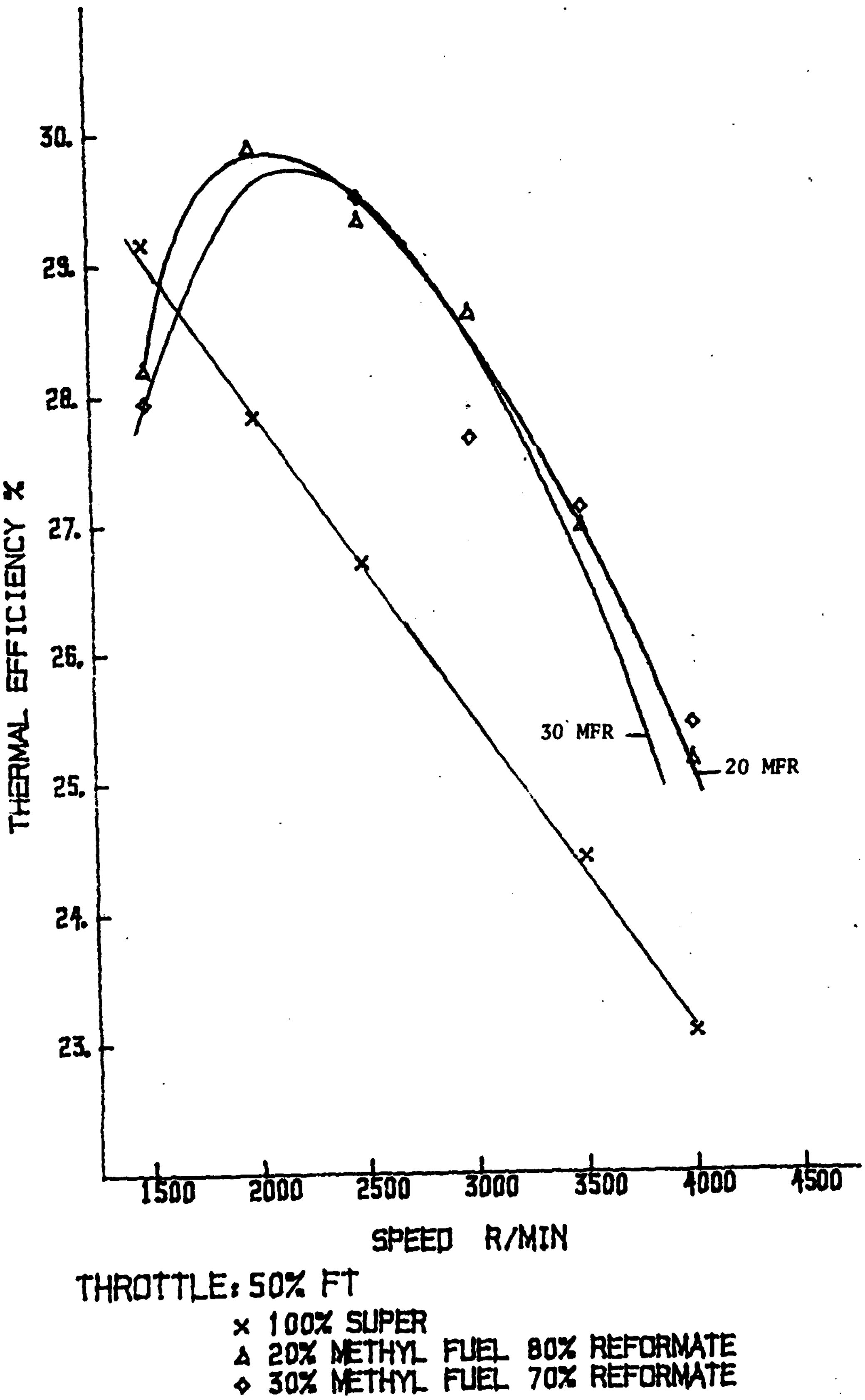

FIG 5 - THERMAL EFFICIENCY vs ENGINE SPEED (50% FT)

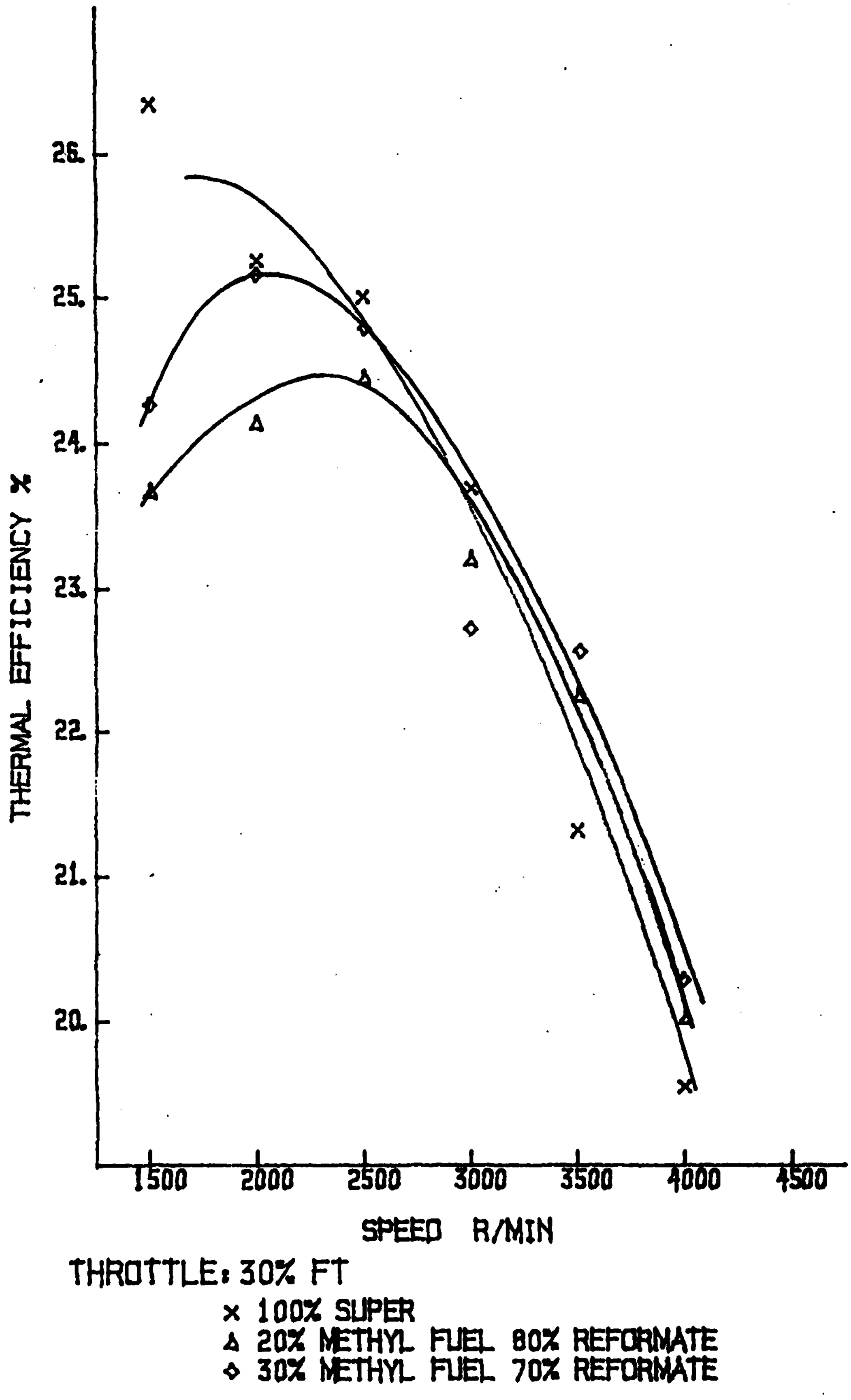

FIG 6 - THERMAL EFFICIENCY vs ENGINE SPEED (30% FT)

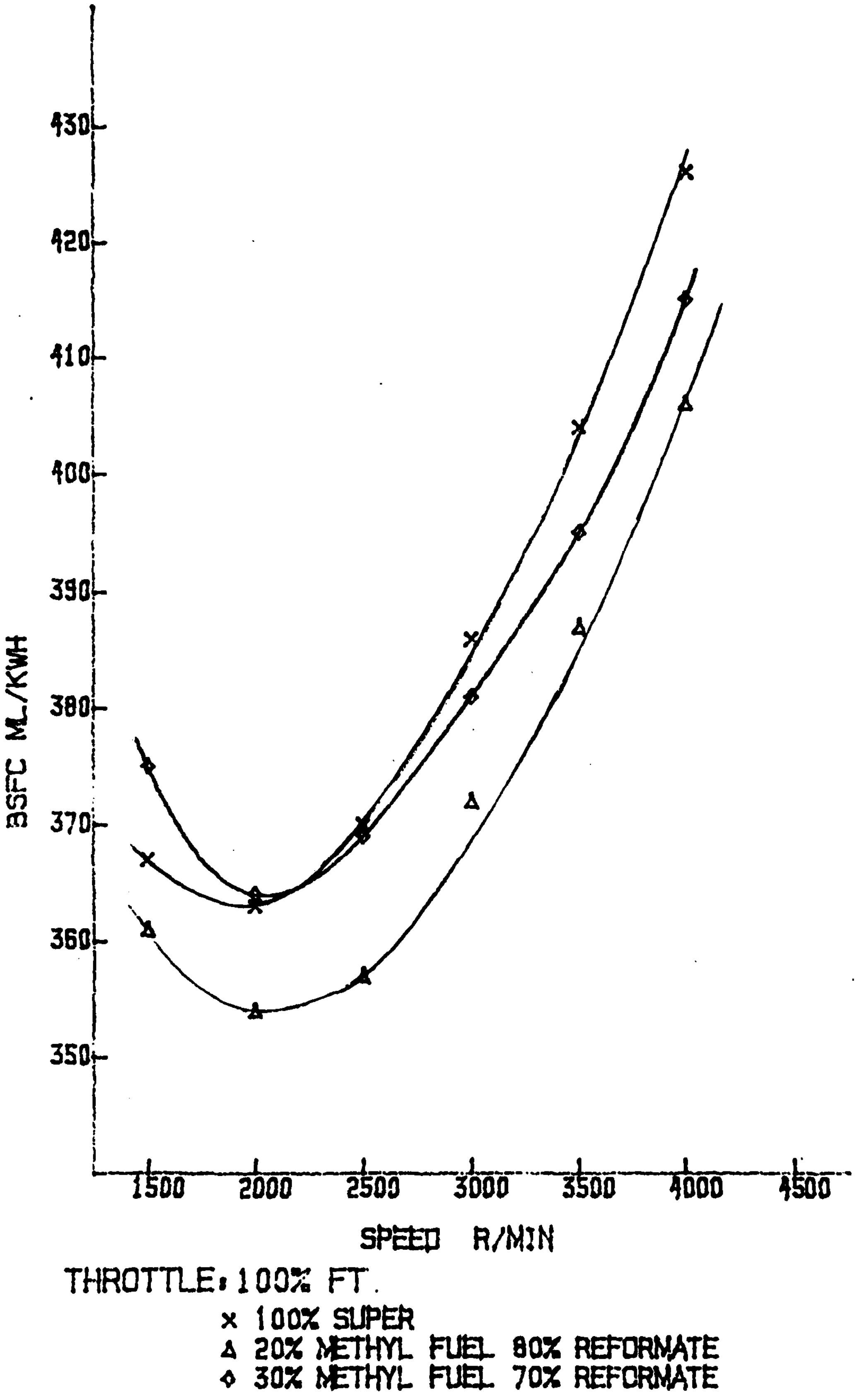

FIG 7 - BSFC vs ENGINE SPEED (100% FT)

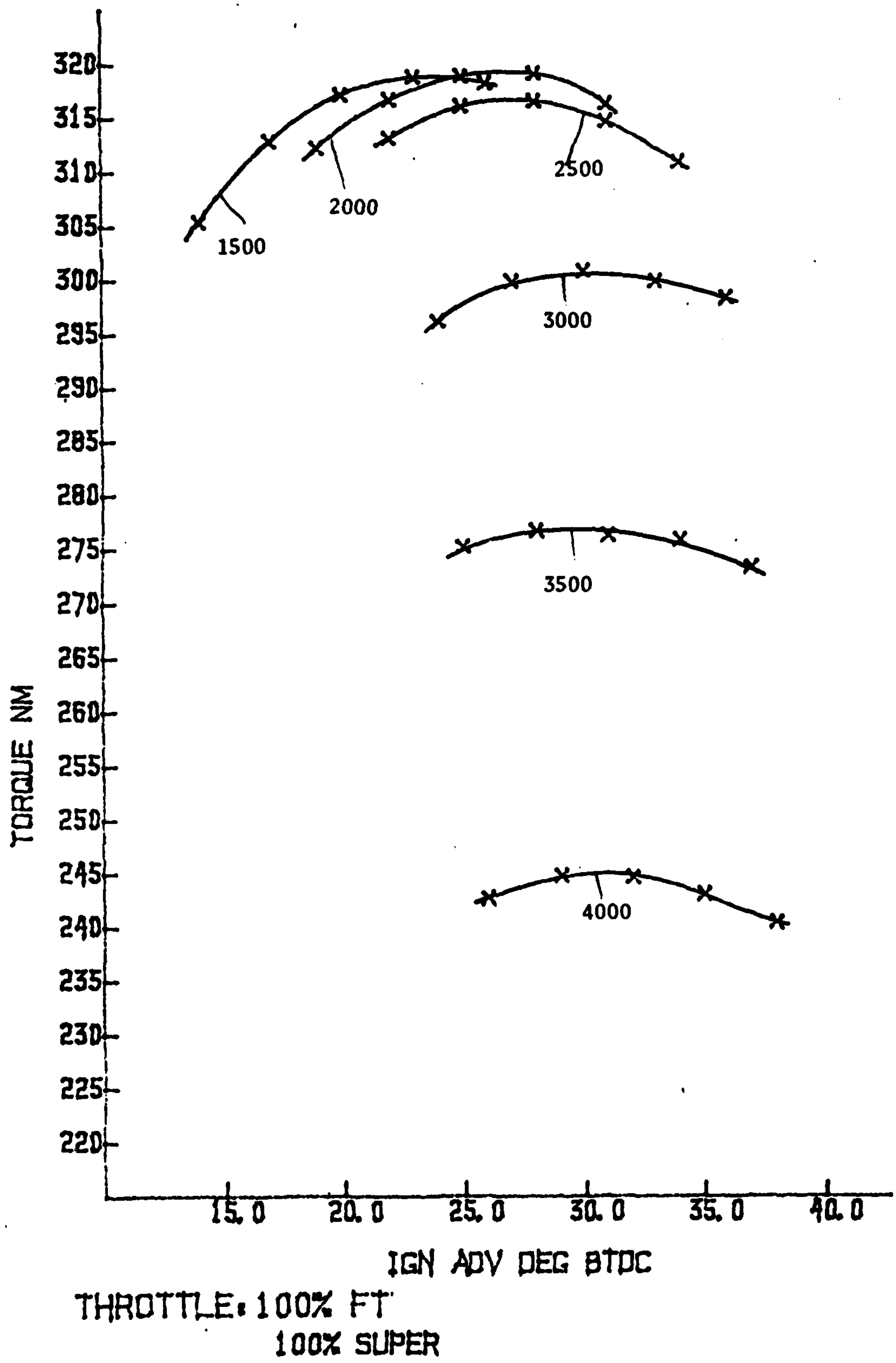

FIG 8 - TORQUE vs IGNITION ADV (MBT)

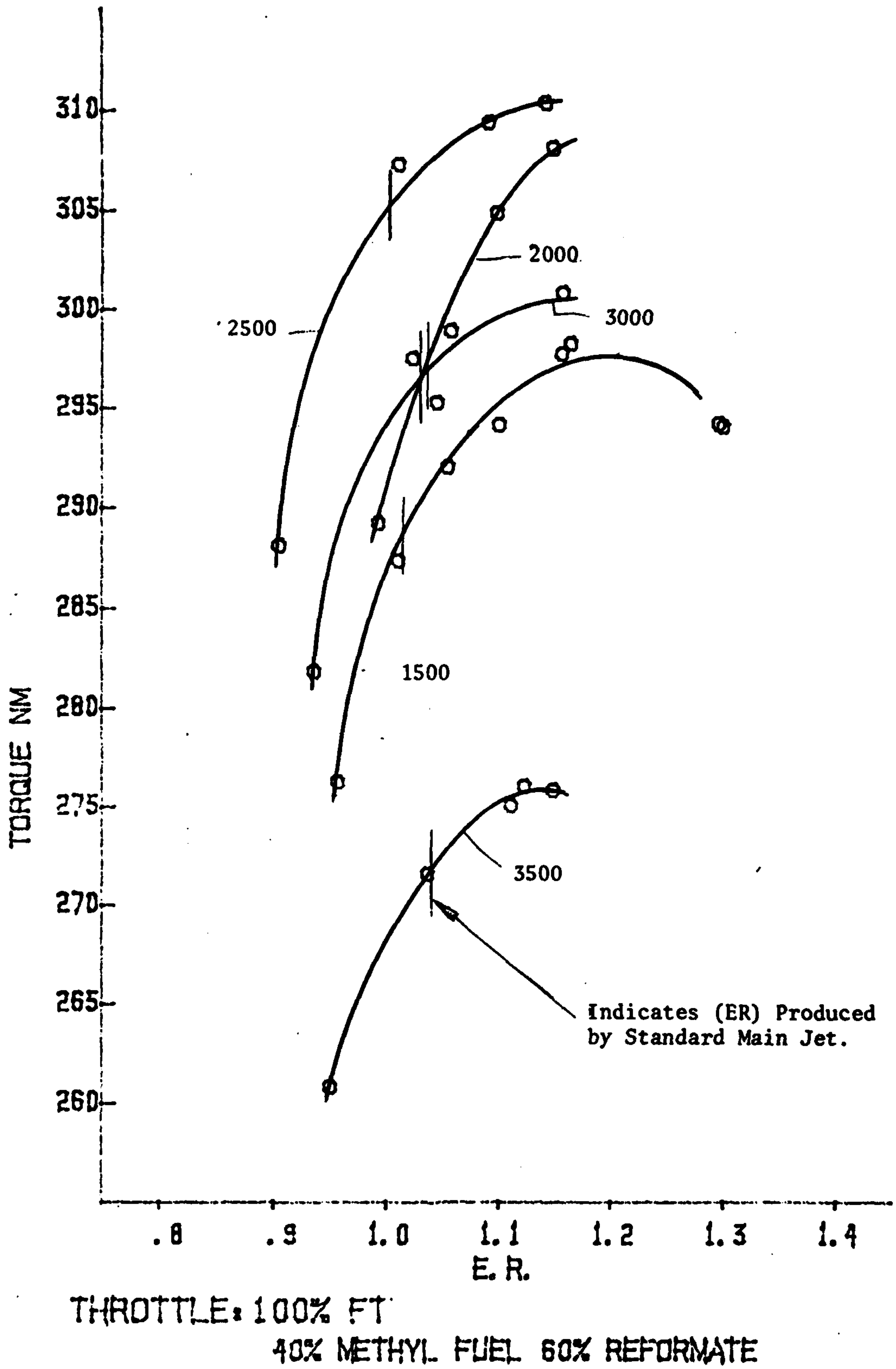

FIG 9 - TORQUE vs (ER) (100% FT)

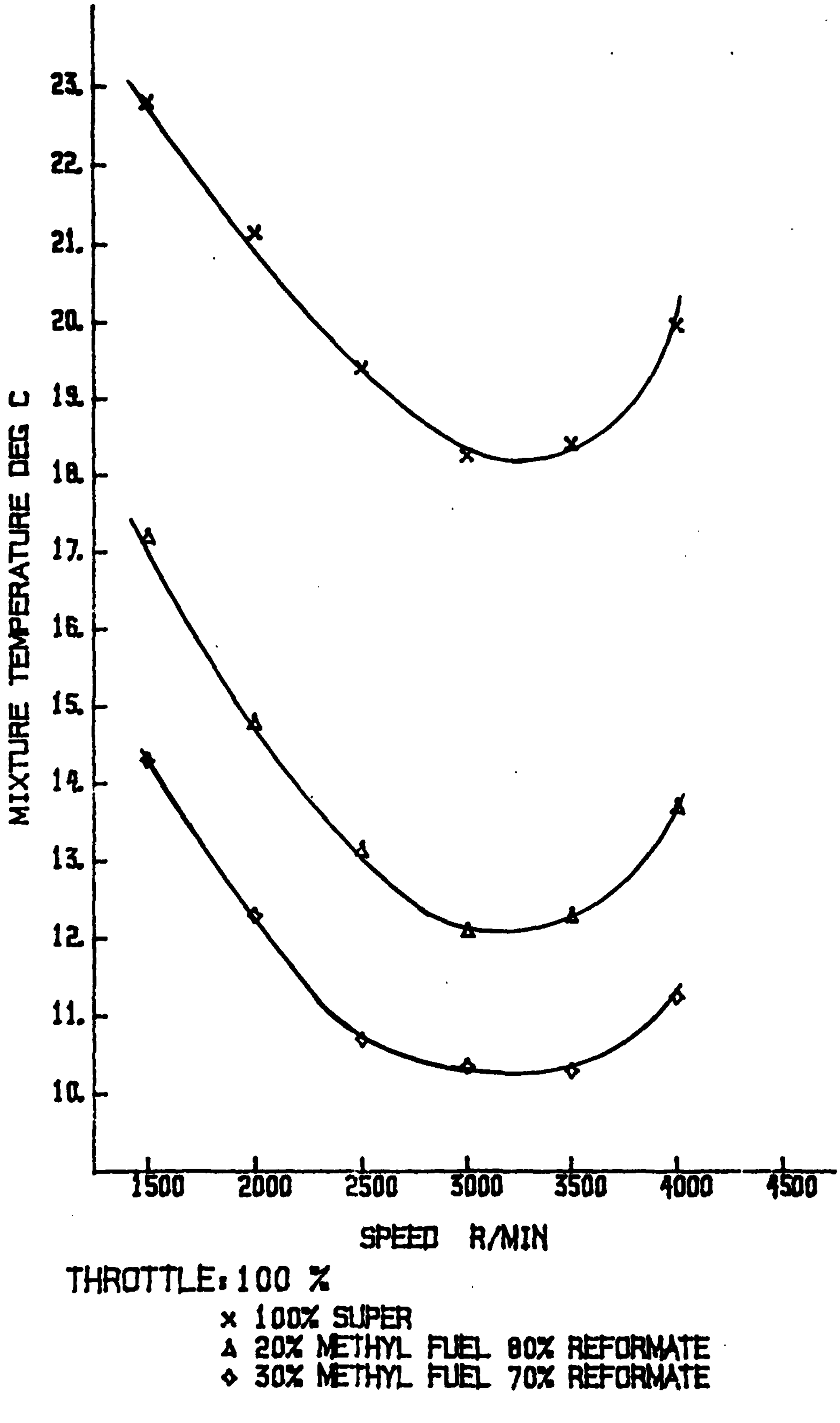

FIG 10 - MIXTURE TEMPERATURE vs ENGINE SPEED (100% FT)

INSTRUMENTATION

1. The parameters measured were:

   a. Torque output by means of a hydraulic dynamometer fitted with an electric load cell.

   b. Engine speed by means of a shaft mounted pulse generator and digital frequency meter.

   c. Intake air flow by measurement of the pressure differential across a selection of airflow nozzles.

   d. Fuel consumption by means of an automatically timed weighing apparatus.

   e. Ignition advance by means of a proprietary phase angle meter designed for the purpose.

   f. ER was derived from air flow and fuel consumption measurements.

FUEL CHARACTERISTICS

1. Methanol. Methanol, known also a methyl or wood alcohol is the simplist alcohol having chemical formula CH_3OH. It is obtained, among other means, by catalytic reforming of natural gas and other fossil fuels. Properties of interest:

a.	Research Octane No	106 minimum
b.	Specific Gravity	.7954
c.	Stoichiometric w/w air/fuel ratio	6.73
d.	Net Calorific Value (NCV)	20 000 J/g
e.	Latent heat of Vaporization	1170 J/g

Chemical composition (analysis by weight)

C 38.43% H 12.76% 0 47.9%

2. Iso-butanol. Iso-butanol is a clear colourless liquid normally used as a solvent. It has the chemical formula $(CH_3)_2$ $CHCH_2OH$. Properties of interest:

a.	Research Octane No	*Not Available* (NA)
b.	Specific Gravity	.8062
c.	Stoichiometric w/w air/fuel ratio	11.1
d.	NCV	33 100 J/g
e.	Latent heat of vaporization	578 J/g

Chemical composition (analysis by weight)

C 64.75% H 13.37% 0 21.5%

3. Reformate. This is a moderately high octane unleaded gasoline produced from low octane naptha feedstocks by a platinum catalytic refining process. It is one of the principal ingredients of pool gasoline from which motor gasoline is produced. Properties of interest:

a.	Research Octane No	95
b.	Specific gravity	0.785
c.	Stoichiometric w/w air/fuel ratio	14.17
d.	NCV	43 500 J/g

e. Latent heat of vaporization NA

Chemical composition (analysis by weight)

C 88.32% H 11.69%

4. Premium Gasoline. Normal commercial premium gasoline. Properties of interest:

a. Research Octane No 95

b. Specific Gravity .758

c. Stoichiometric w/w air/fuel ratio 14.7

d. NCV 46 500 J/g

e. Latent heat of vaporization

5. Calculated Values

Fuel Blends	NCV	Stoichiometric A/F Ratio
20 MFR	39.41	12.89
30 MFR	37.38	12.25
40 MFR	35.36	11.61

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16. Abstract

This document gives the results of investigations into the relative performance of a Ford 4.1 L 6 cylinder engine when operating on super grade gasoline and blends of non-leaded gasoline, methanol and iso-butanol. Satisfactory operation was obtained on fuel blends containing up to 30% total alcohol. Thermal efficiency of the engine was improved for most conditions, but some torque loss was experienced under full throttle at low engine speeds, the loss increasing with increasing proportion of alcohols in the fuel.

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